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Original Article

Retrograde chronic total occlusion percutaneous coronary intervention using single catheter: A single centre registry

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ABSTRACT

Objectives: To analyse the feasibility, safety and procedural outcomes of percutaneous coronary intervention (PCI) for chronic total occlusions (CTO) through retrograde approach using single catheter.
Methods: Our study was a retrospective observational study that enrolled patients who underwent retrograde CTO PCI using a single catheter between June 2016 and February 2020. Clinical success was defined as successful completion of CTO PCI without associated in-hospital major clinical complications like death, myocardial infarction, stroke or urgent revascularisation. Technical success was defined as successful completion of CTO PCI using single catheter and minimum diameter stenosis of <30% with thrombolysis in myocardial infarction (TIMI) flow grade 3, without significant side branch occlusion, flow-limiting dissection, distal embolization, or angiographic thrombus.
Results: Totally 102 patients underwent retrograde CTO PCI during the study period. Out of which, 15 cases were attempted using single catheter. Mean age of the population was 59.1 ± 8.9 years (males: 86.7%) and the left ventricular ejection fraction (LVEF) was (61% ± 9.1%). Mean number of diseased arteries was 2.1 ± 0.7, length of the CTO was 25.5 ± 7.4 mm and J-CTO score was 2.3 ± 0.7. We achieved a technical success rate of 73.3% using single catheter, and the overall clinical success (Including single catheter and ping pong) was obtained in 86.7% cases. One patient (6.7%) developed cardiac tamponade and none of study population required dialysis for contrast induced acute kidney injury (CI-AKI)
Conclusions: Retrograde CTO PCI using single catheter is a technically challenging procedure when compared with other CTO PCI. Our study demonstrated acceptable outcomes which is comparable to other antegrade and retrograde CTO PCI registries.

1. Introduction

CTO are seen in 20% of the patients with coronary artery disease (CAD) referred for coronary angiogram.[1] Only around 10% of the patients with CTO are treated with percutaneous coronary intervention (PCI) and the remaining patients are treated with either coronary artery bypass grafting (CABG) or medications. Technical difficulties and low success rates are the predominant reasons for avoiding CTO PCI. Adaptation of the "hybrid algorithm"[2] during CTO PCI results in higher success rate as shown in various registries[3,4] Retrograde approach is a promising method in lesions where anatomy does not favour antegrade recanalization (ambiguous proximal cap and diffusely diseased distal target etc.), particularly in the presence of suitable collaterals. Retrograde wire crossing is done through epicardial collaterals or, more commonly, the septal collaterals. Retrograde techniques are usually approached through the collaterals from contralateral vessels. Ipsilateral collaterals are infrequently utilised for retrograde approach due to the technical difficulties. Ipsilateral collaterals may be used for retrograde approach using single catheter or two catheters (ping-pong technique). Our study aimed to analyze the procedural outcomes, feasibility, and safety of retrograde CTO PCI using single catheter.

2. Methods

2.1. Study population

Our study was a retrospective observational study which included all patients who underwent retrograde CTO PCI between

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June 2016 and February 2020 at our institution. All the patients were advised revascularisation according to the standard guidelines[5] All the procedures were performed by a single experienced CTO PCI operator (>50 CTO PCI per year) along with his team. Retrograde CTO PCI was tried in cases with good interventional collaterals, ambiguous proximal cap, side branch arising from distal cap, poor distal vessel visualization, or failed antegrade approach. Procedure was stopped when the procedure time extended beyond 3 h, > 3.7 times the estimated glomerular filtration rate (eGFR) of contrast had been used, or when the radiation dose went up > 5 Gy air kerma unless the procedure was well advanced.[6] All patients provided well-informed consent before procedure.

2.2. Definitions

CTO was defined as total occlusion of an arterial segment with thrombolysis in myocardial infarction (TIMI) 0 flow for atleast 3 months[7] Contrast-induced acute kidney injury (CI-AKI) was defined as ≥ 0.3 mg/dL rise in serum creatinine from baseline within 48 h of contrast administration or ≥50% elevation over the course of hospitalization[8] Ambiguous proximal cap was defined as inability to localize the proximal entry point to the CTO lesion. Calcification was identified as readily apparent radiopacities within the vascular wall at the site of the lesion.[9] J-CTO score was calculated for each lesion[10] and collaterals were graded according to the Werner's method[11] Commonly used retrograde wire crossing strategies were (1) retrograde wire escalation, (2) kissing/marker wire technique, and (3)reverse controlled antegrade and retrograde subintimal tracking (CART) (including variations); wire externalization strategies were (1) conventional (externalization wire used across the retrograde microcatheter positioned over antegrade guide catheter), (2) snaring, (3) rendezvous method, and (4) tip in method.

Technical success was defined as successful completion of CTO PCI using single catheter and a minimum diameter stenosis of <30% with TIMI flow grade 3, without significant side branch occlusion, flow-limiting dissection, distal embolization, or angiographic thrombus. Clinical success was defined as successful completion of CTO PCI without associated in-hospital major clinical complications like death, myocardial infarction (MI), stroke or urgent revascularisation.

2.3. Statistical analyses

Continuous variables were presented as mean ± standard deviation and categorical variables were presented as percentage.

3. Results

3.1. Clinical characteristics

Between June 2016 and February 2020, a total of 102 retrograde CTO PCIs were done in our institution. Out of these, 15 cases were attempted using single catheter. Mean age of the population was 59.1 ± 8.9 years. Most of the patients in the study population were males (86.7%). Cardiovascular risk factors commonly seen in this population were type-2 diabetes mellitus (T2DM): 60%, systemic hypertension (HTN): 66.6%, dyslipidemia (DLP): 73.3%, chronic kidney disease (CKD): 13.3%, prior stroke: 13.3%, peripheral arterial disease: 13.3%, and current smoking: 46.7%. Mean left ventricular ejection fraction was in the normal range (61 ± 9.1%). Indications for coronary angiogram and PCI were stable ischemic heart disease (SIHD) with drug refractory angina in 80% of cases and non ST elevation myocardial infarction (NSTEMI) in 20% of cases (Table 1).

Table 1
Baseline clinical characteristics (n = 15).

Baseline Characteristics	Patients (n = 15)
Age (mean ± SD),years	59.1 ± 8.9
Sex:	
Male	13 (86.7%)
Female	2 (13.3%)
T2DM	9 (60%)
HTN	10 (66.6%)
DLP	11 (73.3%)
CKD	2 (13.3%)
Prior stroke	2 (13.3%)
COPD	2 (13.3%)
Peripheral arterial disease	2 (13.3%)
Current smoking	7 (46.7%)
LVEF, mean ± SD, %	61 ± 9.1
Clinical presentation:	
SIHD	12 (80%)
NSTEMI	3 (20%)
STEMI	0

Values are expressed as frequencies (percentages), unless specified otherwise. T2DM, type-2 diabetes mellitus; HTN, hypertension; DLP, dyslipidemia; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; LVEF, left ventricular ejection fraction; SIHD, stable ischemic heart disease; STEMI, ST segment elevation myocardial infarction; NSTEMI, non-ST segment elevation myocardial infarction.

3.2. Angiographic characteristics

Mean number of diseased arteries per patient was 2.1 ± 0.7. Most common artery involved was left circumflex artery (LCX) (53.3%) followed by left anterior descending artery (LAD) (46.7%). Predominantly, the coronary arterial system was left dominant (66.7%) in our study population. Mean length of the CTO was 25.5 ± 7.4 mm. Mean J-CTO score was 2.3 ± 0.7, indicating complex lesion morphologies. Calcifications and moderate to severe tortuosity each were noted in 46.7% of the population. Ambiguous

Table 2
Angiographic characteristics (n = 15).

Angiographic characteristics	Patients (n = 15)
Number of diseased vessels per patient	2.1 ± 0.7
CTO vessel:	
LAD	7 (46.7%)
LCX	8 (53.3%)
RCA	0
Dominance:	
Right	5 (33.3%)
Left	10 (66.7%)
Blunt stump	4 (26.7%)
Ambiguous proximal cap	3 (20%)
Length of CTO, mm	25.5 ± 7.4
Calcification	7 (46.7%)
Moderate- severe tortuosity	7 (46.7%)
Interventional collaterals:	
LAD septal to LPDA septal	6 (40%)
Diagonal to OM	4 (26.7%)
LAD septal to OM	2 (13.3%)
Diagonal to LAD	2 (13.3%)
LAD septal to LAD septal	1 (6.7%)
Collateral channel:	
CC0	0
CC1	11 (73.3%)
CC2	4 (26.7%)
J-CTO score	2.3 ± 0.7
Flush Ostial CTO	0
ISR CTO	0

Values are expressed as or frequencies (percentages), unless specified otherwise. CTO, chronic total occlusion; RCA, right coronary artery; LAD, left anterior descending artery; LCx, left circumflex artery; LPDA, left posterior descending artery; OM, obtuse marginal branch; CC, collateral channel; ISR, in-stent restenosis.

proximal cap was seen in 20% of the study group. We did not have flushed ostial CTO or ISR CTO in our study. Most common interventional collaterals observed in our study group were septal to septal (LAD – left posterior descending artery (LPDA) collaterals (40%). Other collaterals were diagonal to obtuse marginal branch (OM) (26.7%), diagonal to LAD (13.3%), LAD septal to OM (13.3%), and LAD septal to LAD septal (6.7%). Collateral channels were mainly CC1 grade (73.3%) followed by CC2 (26.7%) (Table 2).

3.3. Procedural characteristics

Totally two CTOs (13.3%) were previously attempted and failed and two cases were started as primary retrograde approach. Most common vascular access was right femoral artery (60%) followed by bifemoral access (26.7%), and right radial access (13.3%) We commonly used 7F guiding catheter (93.3%). Sion blue/black (42.9%) and suoh-3 (42.9%) were the commonly used guidewires that crossed collaterals successfully (Fig. 1). Gaia second was the most frequently used guidewire to cross the CTO segment. Mean numbers of guidewires used per patient was 7.3 ± 3.2. In 73.3% cases, more than 5 guidewires were used during the procedure. Septal collaterals (60%) were more frequently used for retrograde wiring than the epicardial collaterals (40%). Finecross (57.14%) was the most common microcatheter used for crossing collaterals followed by caravel (35.7%). Septal collaterals were predominantly crossed with sion black and epicardial collaterals with suoh-3 guidewires. Furthermore, Finecross was used predominantly for septal collaterals and caravel for epicardial collaterals.

Out of 15 cases, guidewire crossed the CTO segment in 14 (93.3%) cases. In all cases, the wire crossing strategy was "retrograde wire escalation" (100%) (Fig. 2). Externalization was done using conventional method in 76.9% cases and snaring in 7.7% cases and rendezvous technique was used in 15.4% cases. In 11 (73.3%) out of 15 cases, procedure was completed with single catheter and

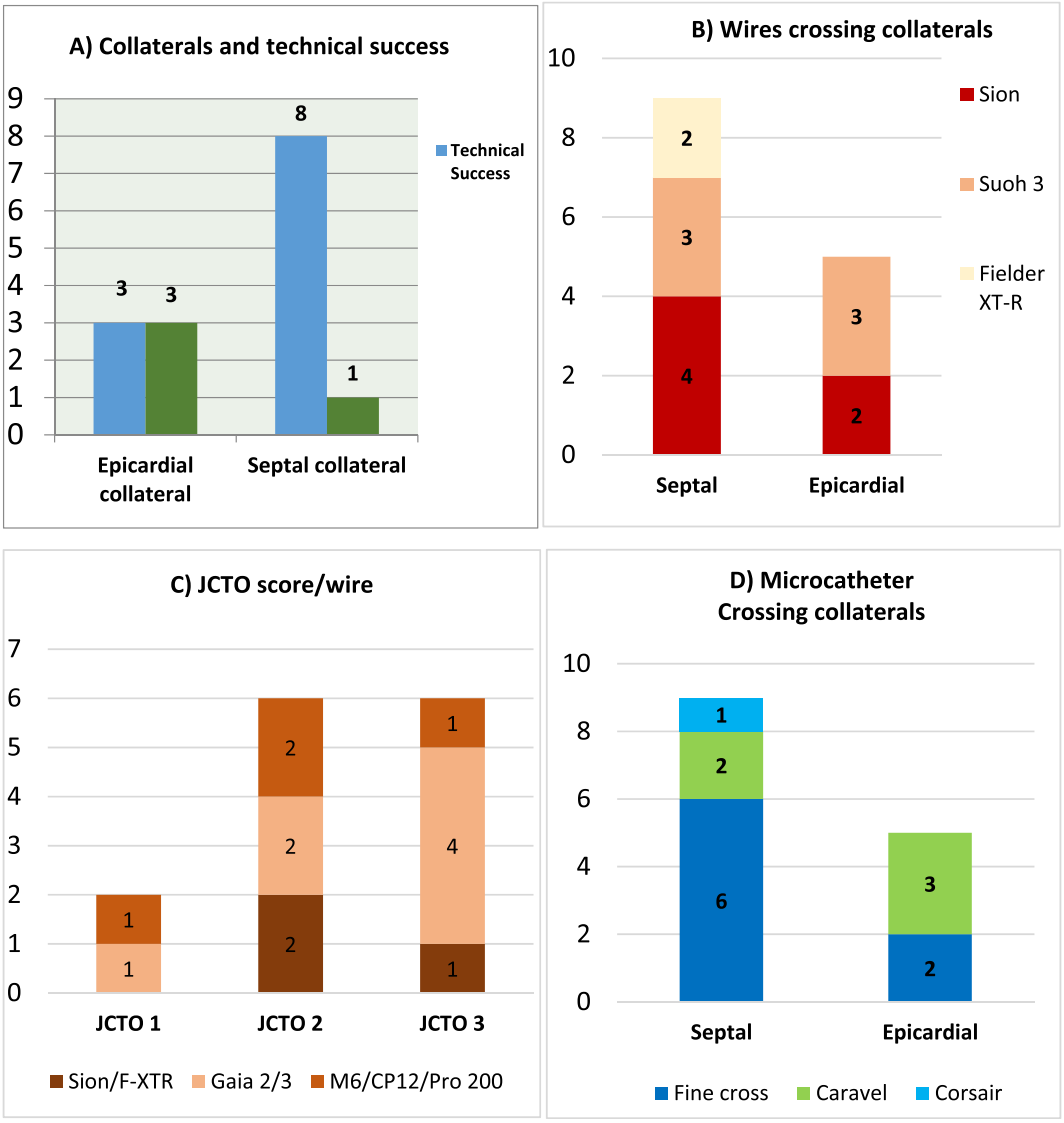

Fig. 1. (A) Technical success through epicardial and septal collaterals (B) Crossing of epicardial and septal collaterals by different wires (C) JCTO score/wire (D) Microcatheter Crossing septal and epicardial collaterals.

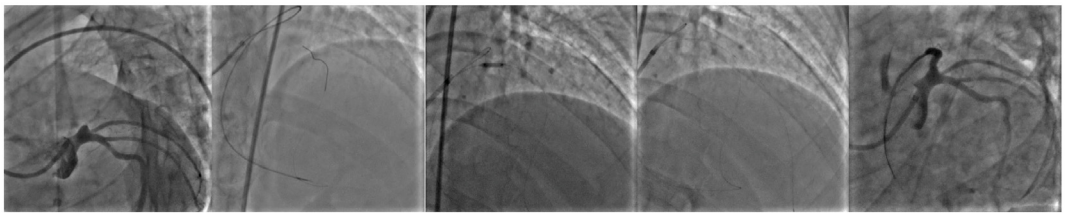

Fig. 2. Case exmaple showing the steps of retrograde CTO PCI using single catheter: A) Ostio-proximal LAD CTO; B) Retrograde guidewire crossing with microcatheter; C) Balloon dilatation of proximal LAD; D) Antegrade wiring of LAD; E) Final angiogram after stenting.

Table 3
Procedural characteristics (n = 15).

Procedure Characteristics	Patients (n = 15)
Previous attempt	2 (13.3%)
Failed antegrade	13 (86.7%)
Primary retrograde	2(13.3%)
Other vessel PCI in same setting	4 (26.6%)
Vascular access:	
Bifemoral	4 (26.7%)
Single femoral	9 (60%)
Femoral and radial	0
Radial/biradial	2 (13.3%)
Guide catheter size	
6 Fr	0
7 Fr	14 (93.3%)
8 Fr	1 (6.7%)
Guide extension used	2 (13.3%)
IVUS used	3 (20%)
Rota/cutting balloon used	1 (6.7%)
Collateral used:	
Epicardial	6 (40%)
Septal	9 (60%)
Guidewire crossing collateral (N=14)	
Sion blue/black	6 (42.9%)
Suoh-3	6 (42.9%)
Fielder FC/XTR	2 (14.2%)
Guidewire crossing CTO (N=14)	
Gaia second/third	7 (50%)
Miracle 6/12	2 (14.3%)
Conquest pro 12	1 (7.14%)
Sion black	2 (14.3%)
Fielder XTR	1 (7.14%)
Others	1 (7.14%)
Total guidewires > 5	11 (73.3%)
Number of guidewires used per patient, mean ± SD	7.3 ± 3.2
Microcatheter crossing collaterals (N=14)	
Finecross	8 (57.14%)
Caravel	5 (35.7%)
Corsair/Corsair pro	1 (7.14%)
Wire crossing techniques (N=14)	
RWE	14 (100%)
Kissing wire technique	0
Reverse CART	0
Externalisation techniques (N=13)	
Conventional	10 (76.9%)
Rendezvous	2 (15.4%)
Snaring	1 (7.7%)
Tip in	0
Wire crossed CTO	14 (93.3%)
Technical success using single catheter	11 (73.3%)
Technical success including ping pong	13 (86.7%)
Clinical success	13 (86.7%)
Contrast volume, mean ± SD, ml	270.7 ± 75.6
Radiation dose, mean ± SD, mGy	8291.13 ± 4316.7
Fluoroscopy time, mean ± SD, min	70.5 ± 31.6

Values are expressed as frequencies (percentages), unless specified. PCI, percutaneous coronary intervention; IVUS, intravascular ultrasound; CTO, chronic total occlusion; RWE, retrograde wire escalation; CART, controlled antegrade and retrograde subintimal tracking; Fr, French; mGy, milligray.

in two other cases externalization required “ping-pong method” (using two guide catheters). Procedure could not be completed in two cases (13.3%) (Table 3). In the first case, after retrograde guidewire crossing the CTO, both retrograde and antegrade microcatheters (using tip-in method) could not cross the CTO segment. Hence externalization and further stenting could not be done. In another case, we could not cross the collateral channel with guidewire. Moreover, the second failure case had chronic kidney disease (CKD). Hence the usage of contrast was very much restricted. In both cases, other vessel PCIs were also done in the same setting. Hence, we had limitations in the contrast volume and radiation dose. CI-AKI developed in four cases (26.6%) but none of them required dialysis. One patient developed LAD perforation and cardiac tamponade (6.7%), but he was revived after immediate pericardiocentesis and covered stent implantation. Two patients developed septal collateral perforation (Fig. 3) and both were hemodynamically stable (Table 4).

4. Discussion

Retrograde CTO PCI is considered one of the final frontiers in the field of interventional cardiology. CTOs with ambiguous caps, flush aorto-ostial occlusion, and poor distal target vessel are some of the lesion morphologies, that favor primary retrograde approach for CTO recanalization[2] Failure to cross the lesion via antegrade approach is another common scenario where retrograde approach is attempted. Retrograde approach increases the success rate of CTO PCI in complex subsets.[3] Comparing “Antegrade only” approach, retrograde approach has higher complication rates,[12] however, the long term outcome is equally good.[13] Retrograde CTO PCI can be attempted through septal and epicardial collaterals or bypass grafts. Epicardial collaterals are not preferred routinely in retrograde approach, since the rate of cardiac tamponade is higher than the septal collateral crossing.

Retrograde CTO PCI is usually approached through contralateral collateral channels using two guide catheters. Ipsilateral collateral channels may also be used in cases where contralateral collaterals are unsuitable for PCI.[14] CTO PCI using ipsilateral collaterals can be done using single catheter or two catheters (ping pong technique).[15] Single catheter technique needs expert technical skills because of acute angles in the course of ipsilateral collaterals. Furthermore, the complications are more since ipsilateral collaterals are often epicardial in course.

We achieved a technical success rate of 73.3% using single catheter, which is comparable to other CTO trials and registries. Procedural success rate of retrograde CTO PCI, observed in Euro CTO registry is 75.3%[13] Another study which was specifically done on CTO PCI using ipsilateral collaterals (including single catheter and ping pong technique) showed a technical success rate of 87%[16] It appears that ipsilateral interventional collaterals are uncommon in right coronary artery (RCA) since none of our cohort had RCA CTO. Both LAD and RCA receive collaterals from the opposite system,

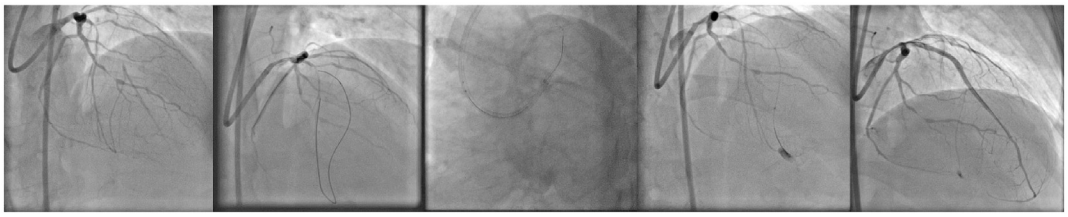

Fig. 3. Another case example showing complication: A) Mid LAD CTO with major septal artery filling the distal vessel; B) Retrograde guidewire across septal–septal; C) Rendezvous technique; D) Septal hematoma; E) Final angiogram after stenting.

more commonly through septal collaterals. Hence both LAD and RCA are commonly approached through contralateral collaterals rather than ipsilateral collaterals. Similar observation has been made in other registry which studied CTO PCI using ipsilateral collaterals[16]

One case of pericardial effusion with tamponade (6.7%) was observed in our cohort. The reason for the pericardial effusion was major coronary perforation because of the high pressure balloon dilatation in the calcified lesion. We observed collateral perforation in two cases. Since both collateral perforations are from septal collaterals, pericardial effusion did not develop. Despite the use of epicardial collaterals in 40% of cases, no epicardial collateral perforation was seen in our study. We did not observe any mortality, stroke, or acute stent thrombosis in our study. Though we had 4 cases of CI-AKI as per Kidney Disease: Improving Global Outcomes (KDIGO) definition, none of our patients required dialysis including two patients with CKD.

Technical difficulties were commonly observed during retrograde single catheter retrograde CTO PCI. Firstly, we had to use epicardial collaterals frequently. Because of the tortuosity and steep angles of the epicardial collaterals, guidewire and microcatheter manipulations across the collaterals were difficult. In addition, manipulation of the microcatheters across the CTO segment was also difficult. Secondly, more than 60% of our study population had left dominant system. Any reduction in flow across left main coronary while using larger size catheters might become life threatening, particularly while using two microcatheters. In general, “reverse controlled antegrade and retrograde subintimal tracking (reverse CART)” is a technically difficult procedure in single catheter retrograde CTO PCI. Usage of 8F catheters may facilitate easier balloon tracking alongside the microcatheter in reverse CART. Donor artery dissection, which is frequently seen in retrograde CTO PCI, is extremely dangerous in left dominant circulation. Thirdly, externalization of the guidewire is more difficult while using single catheter. Though conventional externalisation method is easier while using contralateral guide catheter, it is difficult in single catheter interventions, particularly in LCX CTO, because of the angulation it makes with the guide catheter. Finally, after guidewire externalisation, taking the retrograde microcatheter into the guiding catheter is extremely difficult, particularly in calcified lesions. The reason is that, balloon trapping of the retrograde wire inside the guiding catheter, which usually facilitates the pushing of retrograde microcatheter into the guiding catheter, can not be done. In our study, we needed ping pong method in two cases for externalization.

Technical failures are commonly seen in severely calcified vessels, using epicardial collaterals and also in cases where other vessels PCI are done. It is always preferable to do these kinds of complex procedures as standalone elective case rather than combining with other vessel PCI. Two cases of technical failures in our study were due to the above mentioned reasons. In the first case, extensive calcification prohibited the crossing of microcatheter across CTO segment. In the second case, patient was having CKD and the LAD lesion was stented first. Hence, we had restrictions in the usage of contrast.

The major advantage of this technique is that it reduces the technical failure rate in CTO PCI. When the antegrade approach fails and no contralateral collaterals are available, retrograde approach through ipsilateral collaterals increases the chance of successful revascularisation. This is particularly helpful when antegrade approach fails in a left dominant circulation, where retrograde CTO PCI through ipsilateral collateral may be the only option.

Table 4
Complications.

Type of Complication	Patients (n = 15)
CI-AKI (>0.3 mgs% increase)	4 (26.6%)
CI-AKI requiring dialysis	0
Major coronary perforation	1 (6.7%)
Collateral perforation	2 (6.7%)
Cardiac tamponade	1 (6.7%)
Major artery dissection	1 (6.7%)
Stent thrombosis	0
Stroke	0
Major bleeding	0
Urgent revascularisation (PCI/CABG)	0
Death	0

Values are expressed as frequencies (percentages). CI-AKI, contrast-induced acute kidney injury; PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting.

5. Study limitations

Our study was a retrospective observational study with limited number of cases. Larger study population is needed to properly analyze the factors associated with technical failures in this complex subset of CTO interventions. Also, long term follow-up data is not available to analyze the outcome comparing CTO PCI using contralateral collaterals.

6. Conclusion

Retrograde CTO PCI using ipsilateral collaterals and single catheter is technically feasible, though they represent complex subset of CTO PCI in terms of lesion morphology and technical difficulties. The success rate in our study population is comparable to other trials and registries. Operator skills and experience in retrograde CTO PCI play major roles in the success of this complex subset.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ihj.2021.06.006.

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